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Neutron Diffraction Investigations of $(CoMn)_{1-x}Fe_x$*

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The spin structure and the atomic ordering of fcc $(CoMn)_{1-x}Fe_x$ have been investigated by powdered and the single crystals. The spin structure was determined to be similar to that of γ-Fe, where the inclination angle of spins and the temperature dependence of the sublattice moment were given. No atomic ordering in this system was confirmed, and some diffuse scattering of CoMn around the $(100)_M$ reflection just below the Néel point was found. A universal relationship between the Néel point and the lattice parameter for the γ-Fe like antiferromagnetic alloys was found and an interpretation about the fundamental magnetic properties reported in the preceding paper was given.

§1. Introduction

In the preceding paper,[1] the magnetic properties of the ternary system Co-Mn-Fe in fcc structure have been investigated in details, above all, it was concluded that the antiferromagnetic properties of $(CoMn)_{1-x}Fe_x$[1,2] are similar to that of γ-Fe, and the gap type anomaly of the electrical resistivity at Néel point was found.

The antiferromagnetic spin structure of γ-Fe has been determined by neutron diffraction experiment,[3] where the fcc precipitated Fe into Cu was used, and the structure was obtained to have the first kind ordering of fcc lattice so called CuAu type spin ordering with an inclination of spin direction from the four-fold axis of the lattice. Very recently, Ishikawa *et al.*[4] have determined the spin structure of non-ferromagnetic stainless steel denoted as $(CrNi)_{0.30}Fe_{0.70}$ with disordered fcc structure and they reported that the spin structure and the moment are similar to those of γ-Fe, where the e/a-value (outer d-electrons per atom) keeps to 8. While Ishikawa *et al.*[4,5] have also investigated the spin structure of the whole range of fcc Fe-Mn system by adding of a small quantity of Cu and C, and they gave three kinds of spin structure as follows: the γ-Mn like and the γ-Fe like colinear CuAu type spin structures for the Mn-rich ($7 \leq e/a \leq 7.3$) and the Fe-rich ($7.8 < e/a \leq 8$) sides respectively, and a non-colinear tetrahedral spin arrangement for the intermediate region ($7.4 < e/a < 7.8$). Basing on the band calculation with a self consistent exchange interaction, Asano and Yamashita[6] gave the atomic moments of antiferromagnetic γ-Mn as well as γ-Fe as 2.3 μ_B and 0.7 μ_B respectively, which agrees with the experimental results of γ-Mn, γ-Fe and γ-Fe-Mn alloy.

On the other hand, from the metallurgical standpoint, the atomic ordering in the fcc phase of the binary Co-Mn and the ternaly Co-Mn-Fe systems has not been hitherto determined. Some reports on the ordering Co_3Mn and CoMn[7] have been published, however the results was speculated from the thermal measurements. While the existence of the atomic diffuse scattering by means of neutron diffraction has been reported for the polycrystalline samples of Co-Mn alloys.[8]

As mentioned above, the neutron diffraction investigations concerning on the magnetic as well as the atomic orderings implies so many problems. In planning of the experiments, it is worthwhile to note that the nuclear scattering amplitude of Mn is negative, while those of Co and Fe are positive. The situation is very convenient to examine the atomic long range and short range orderings, however, it is difficult to determine the magnitude of the small antiferromagnetic moment in the disordered lattice by the comparison with the very weak nuclear reflection. Then, the single crystals were mainly used in this experiment.

§ 2. Sample Preparation and Arrangements of the Experiment

Single crystals $Co_{0.52}Mn_{0.48}$ and $(CoMn)_{0.75}Fe_{0.25}$

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were grown by Bridgman method from the polycrystalline ingots with pre-adding of small amount of Mn to adjust the evapolated Mn composition as mentioned in the preceding paper.[1] The maximum temperature of the furnace was 1300°C, the maximum temperature gradient is 50°C/cm and the sample was set down by the velocity of 6.4 cm/hr. After this, for the homogenization the sample was re-heated in an evacuated silica tube at 950°C for more than one day and then cooled in air to room temperature. The dimension of both the samples was about 10 mmϕ and 14 mm length in the cylindrical shape. The compositions were determined from the powdered X-ray diffraction, where the powders were shaved from upper and lower parts of the single crystal. The estimated compositional error was given to be less than 0.5% in their lattice parameters.

On the other hand, the powdered samples were also prepared for $Co_{0.25}Mn_{0.75}$, $Co_{0.64}Mn_{0.36}$, $Co_{0.50}Mn_{0.50}$ and $(CoMn)_{0.75}Fe_{0.25}$. For each sample, about 50 gram of the powder with ca. 200 mesh was made in Ar-atmosphere to avoid any oxidations. The samples were quenched or annealed with the perpose to determine the atomic ordering at high or low temperature, and some confirmations for the diffraction result of the single crystal were done. It is noted that the sample $Co_{0.57}Mn_{0.43}$ corresponds to the null matrix for the nuclear reflections.

The diffraction experiments were carried out at Research Reactor Institute, Kyoto University (KUR). Before the diffractions of the single crystals, some preliminary arrangements were done. The wave length was determined to be 0.996 A from the diffraction of Cu-powder. The coupling between the single crystal and the beam was checked by flat-top method and the $\lambda/2$-contamination was examined by the $\lambda/2$ positions of some nuclear reflections, which are independent of the antiferromagnetic reflection, thus the contamination was observed to be less than 10^{-4} for the nuclear reflections. So far as the examination of extinction effect of our single crystals was concerned, it is not sufficient to compare the reflection intensities between single and powder crystals owing to the weak nuclear reflections of the powdered sample as mentioned above. Then, observing the intensities of several sets of the nuclear reflections with the equivalent indices $\{hkl\}_N$ which contain an absorption effect due to the cylindrical shape, it was obtained that the intensities of the equivalent indices agree each other within the difference of 5% and the relative intensities for the different indices coincide with those of calculated value within the reliable factor of a few percents. Thus, the extinction as well as the absorption effects of our single crystals were considered to be not so large, so the observed intensities were used directly for the analysis described below.

The temperature variations for the single crystals were measured from 78 K to 450 K in the cryostat under the heater control of ± 1 K, where the thermocouple of chromel-constantan was used. For the powdered crystals $Co_{0.64}Mn_{0.36}$, $Co_{0.50}Mn_{0.50}$ and $(CoMn)_{0.75}Fe_{0.25}$, a cryostat for liquid He was used. The background of the cryostat was subtracted carefully.

§ 3. Results Obtained

A. The diffractions of the powdered samples

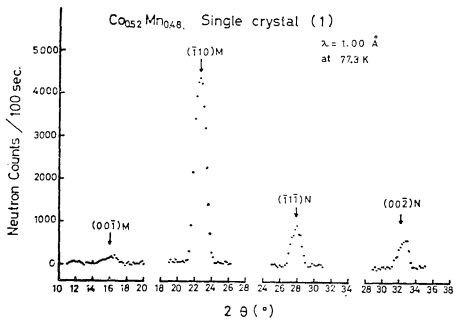
The atomic ordering were examined by the annealed samples of $Co_{0.75}Mn_{0.25}$, $Co_{0.64}Mn_{0.36}$ and $Co_{0.50}Mn_{0.50}$ at room temperature. No superlattice reflections for the all could be observed. In addition to this, any distinct diffuse reflections due to the atomic short range order, which has been reported by Bacon and Cowlan[8] for the powdered samples of $Co_{0.41}Mn_{0.59}$ and $Co_{0.575}Mn_{0.425}$ near the (100) position, could not also be confirmed for the annealed and quenched samples shown above, and this result will be reconfirmed by our single crystals. Therefore, the atomic ordering of the Co–Mn–Fe system is concluded to be nearly perfect disorder.

Next, in order to check the antiferromagnetic spin ordering, the diffraction experiments for the samples $Co_{0.64}Mn_{0.36}$, $Co_{0.50}Mn_{0.50}$ and $(CoMn)_{0.75}Fe_{0.25}$ were carried out at the temperature of 4.2 K and 77.3 K respectively. In the preceding report,[1] from their susceptibility measurements the Néel point has been obtained as 40 K, 390 K and 310 K respectively. The diffraction results showed that the any distinct magnetic as well as nuclear reflections can not be observed for the samples $Co_{0.64}Mn_{0.36}$ and $Co_{0.50}Mn_{0.50}$, where the reflections fell into back ground. While for the $(CoMn)_{0.75}Fe_{0.25}$, it was found that the weak nuclear reflections having fcc indices and some weak magnetic ones which can be indexed as CuAu type magnetic ordering. However, these reflections were too weak to determine the spin moment and the direction. Thus, it can be presumed that the spins of the antiferromagnetic γ-phase of Co–Mn–Fe possess the CuAu type

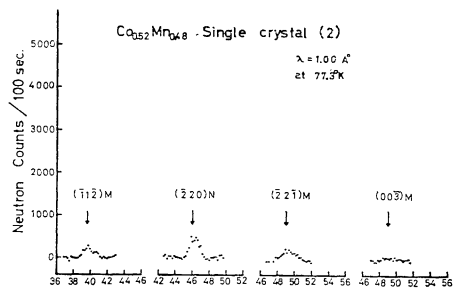
(γ-Fe like) structure except for the side of $Mn_{1-x}Fe_x$ ($0.4<x<0.8$).[5] The antiferromagnetic moment can be estimated as less than 1 μ_B. The exact moment will be obtained from the single crystals as shown below.

B. The single crystal diffractions of $Co_{0.52}Mn_{0.48}$ and $(CoMn)_{0.75}Fe_{0.25}$

The determination of the detailed spin structure was carried out at liquid nitrogen temperature for the single crystals $Co_{0.52}Mn_{0.48}$ and $(CoMn)_{0.75}Fe_{0.25}$. The several nuclear as well as magnetic reflections in the (110) reciprocal lattice



(a)



(b)

Fig. 1(a), (b). Neutron diffraction patterns of the single crystal $Co_{0.52}Mn_{0.48}$ at 77.3 K ($\theta-2\theta$ scan).

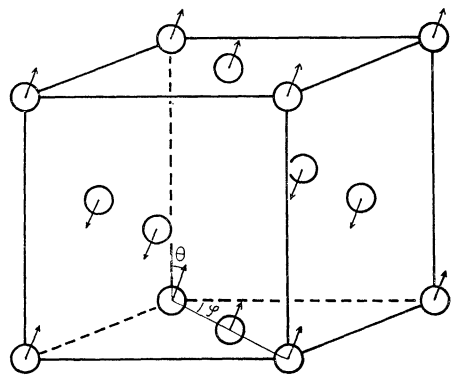


Fig. 2. Spin structure of $(CoMn)_{1-x}Fe_x$ (CuAu type ordering). The θ and ϕ are the polar and the azimuthal angles respectively.

plane of fcc structure were measured by $\theta-2\theta$ scans. The results for $Co_{0.52}Mn_{0.48}$ is shown in Fig. 1, where the magnetic peaks correspond to the antiferromagnetic reflections of CuAu type illustrated in Fig. 2. The observed intensities for both single crystals are indicated in Table Ia and Ib.

In the case of $Co_{0.52}Mn_{0.48}$, the highest peak is the magnetic $(\bar{1}10)_M$ and the others are weak, and the non-existence of atomic ordering was reconfirmed. The appearance of weak $(00\bar{1})_M$ suggests a small inclination of spin axis described below. It is noted that the $(00\bar{1})_M$ peak was not so diffuse at 77.3 K, however, this peak broaden out at near the Néel temperature as shown below. While, the stronger nuclear reflections without atomic ordering can be obtained in $(CoMn)_{0.75}Fe_{0.25}$ (Table Ib), and the magnetic reflection disappears at $2\theta>70°$.

Neglecting the extinction and absorption effect from the reason mentioned above, the results were analysed by the following equations.[5] The intensity of nuclear reflection is given as

$$I_N=kV(\sin 2\theta_B)^{-1}|F_N|^2 e^{-2M}, \quad (1)$$

where k, V and $(\sin 2\theta_B)^{-1}$ are a constant, the volume and Lorentz factor respectively, and the structure factor F_N in the (110) plane is given to be

$$\begin{cases} F_N=4\bar{b}^2 & \text{for all even or all odd } h, k, l, \\ F_N=0 & \text{for the others,} \end{cases} \quad (2)$$

and where the average scattering amplitude $\bar{b}$ is obtained from $b_{Co}=(0.28\pm0.01)\times10^{-12}$, $b_{Mn}=-(0.37\pm0.01)\times10^{-12}$ and $b_{Fe}=(0.95\pm0.01)\times10^{-12}$ cm.[9] The Debye temperature $\theta_D=450$ K was tentatively used for the Debye-Waller factor e^{-2M}, where the effect is estimated to be less than 4% for our experiments. While, in the magnetic reflection,

$$I_M=kV(\sin 2\theta_B)^{-1}|F_M|^2e^{-2M}(e^2\gamma/mc^2)^2\bar{S}^2f^2, \quad (3)$$

where the square of the magnetic structure factor for the CuAu type structure in the (110) plane is expressed to be

$$\begin{cases} |F_M|^2=(16/3s^2)\{s^2-(h\sin\theta\sin\phi \\ \qquad +k\sin\theta\cos\phi+l\cos\theta)\}^2, \\ \text{with} \quad s^2=h^2+k^2+l^2, \\ \qquad \text{for even } h, k \text{ and odd } l \text{ or odd } h, k \\ \qquad \text{and even } l, \\ F_M=0, \quad \text{for the others,} \end{cases} \quad (4)$$

where the spin direction is denoted by the polar

angle θ measured from the four-fold c-axis and the azimuthal angle ϕ from the two-fold b-axis as shown in Fig. 2. It is noted that the factor 1/3 in above expression is due to the effect of the three antiferromagnetic domains having the x-, y- and z-layers in CuAu type spin arrangement with the same volume which will be confirmed below. The intensity containing the spin inclination can be written as follows.

$$\begin{cases} |F_M(00\bar{1})|^2=(16/3)\sin^2\theta\ , \\ |F_M(\bar{1}10)|^2=(8/3)\ (2-t^2)\ , \\ |F_M(\bar{1}1\bar{2})|^2=(8/9)\ \{6-(t-2\cos\theta)^2\}\ , \\ |F_M(\bar{2}2\bar{1})|^2=(16/27)\ \{9-(2t-\cos\theta)^2\}\ , \\ \text{where}\quad t^2=\sin^2\theta(1-\sin 2\phi)\ . \end{cases} \qquad (5)$$

The angles θ and ϕ will be determined from these equations.

To determine the magnetic moment $\bar{S}$, it was used the nuclear reflections shown above and the magnetic form factors obtained from diffraction experiments, that is, f_{Co} by Nathans and Paoletti[10] for the fcc Co and f_{Mn} by Antonini *et al.*[11] for the ordered fcc $MnPt_3$. The examination of the antiferromagnetic domain effect was done by the torque measurement for the same single crystals. The obtained magnitude of the torque amplitude in the (110) plane was less than 6 erg/cc under 10.8 kOe at 77.3 K. If the single domain structure is assumed, the torque due to the difference of paralell and perpendicular susceptibilities for the co-linear spin structure is estimated to be 1.6×10^3 erg/cc under the circumstance. In consequence, it is justified that the three domains have the same volume within the difference of 0.4%.

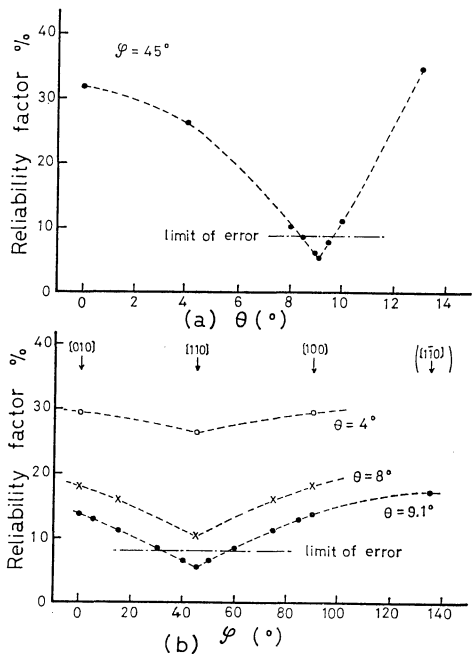


Fig. 3. The reliability factors of the diffraction results of $Co_{0.52}Mn_{0.48}$ for the variations of θ and ϕ.

The spin inclination was determined from the above equations so as to find the minimum reliability factor as the functions of θ and ϕ, which is shown in Fig. 3 in the case of $Co_{0.52}Mn_{0.48}$. The angles at 77.3 K are given to be $\theta=9.1\pm0.5°$, $\phi=45°$ and $\theta=6.7\pm0.7°$ $\phi=45°$ for $Co_{0.52}Mn_{0.48}$ and $(CoMn)_{0.75}Fe_{0.25}$ respectively. Next, the average moment $\bar{\mu}$ at 77.3 K was obtained from the ratio between the magnetic and nuclear reflections as 0.56 ± 0.21 μ_B and 0.67 ± 0.07 μ_B respectively, where as for the intensity of $(100)_M$, the average value of the three times measurements was used. The errors produce mainly from that

Table Ia. The calculated and the observed intensities of $Co_{0.52}Mn_{0.4}$ at 77.3 K.

$h\ k\ l$	$(I_i/\sum_i I_i)_{cal.}\times10^3$	$(I_i/\sum_i I_i)_{obs.}\times10^3$
$(0\ 0\ \bar{1})_M$	28.4	28.8
$(\bar{1}\ 1\ 0)_M$	633.0	636.0
$(\bar{1}\ 1\ \bar{2})_M$	36.7	35.8
$(\bar{2}\ 2\ \bar{1})_M$	36.1	41.0
$(0\ 0\ \bar{3})_M$	1.1	0
$(\bar{1}\ 1\ \bar{1})_N$	105.4	106.5
$(0\ 0\ \bar{2})_N$	92.1	88.3
$(\bar{2}\ 2\ 0)_N$	67.3	63.6

Table Ib. The calculated and the observed intensities of $(CoMn)_{0.75}Fe_{0.25}$ at 77.3 K.

$h\ k\ l$	$(I_i/\sum_i I_i)_{cal.}\times10^3$	$(I_i/\sum_i I_i)_{obs.}\times10^3$
$(0\ 0\ 1)_M$	1.03	1.00
$(\bar{1}\ 1\ 0)_M$	40.72	40.32
$(\bar{1}\ 1\ 2)_M$	2.13	2.20
$(\bar{2}\ 2\ 1)_M$	2.35	2.11
$(0\ 0\ 3)_M$	0.04	0.32
$(\bar{2}\ 2\ 3)_M$	0.15	0.28
$(\bar{3}\ 3\ 0)_M$	0.23	0.23
$(\bar{1}\ 1\ 1)_N$	263.1	260.1
$(0\ 0\ 2)_N$	231.6	221.6
$(\bar{2}\ 2\ 0)_N$	168.0	164.0
$(\bar{1}\ 1\ 3)_N$	147.3	154.3
$(\bar{2}\ 2\ 2)_N$	142.2	153.2

of the nuclear scattering amplitude of the elements and that of the composition of the alloy estimated as $\pm 0.5\%$. In Tables I(a) and I(b), the calculated and the observed intensities are exhibited, and the reliability factor for the total reflections is given as 1.9% and 3.1% for $Co_{0.52}Mn_{0.48}$ and $(CoMn)_{0.75}Fe_{0.25}$ respectively.

C. *The temperature dependence of the average moment*

The temperature dependence of the average moment was obtained from the measurements of the $(\bar{1}10)_M$ intensity and the dependence from absolute zero to the Néel point was given. The results of $Co_{0.52}Mn_{0.48}$ and $(CoMn)_{0.75}Fe_{0.25}$ are shown in Fig. 4. The moment at 0 K can be

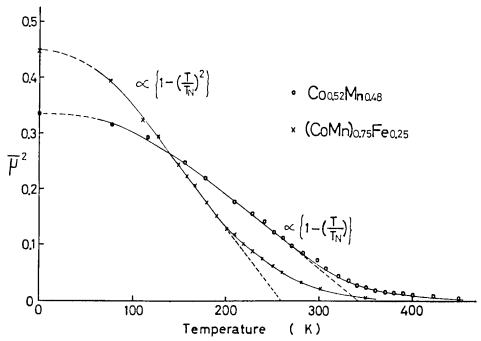


Fig. 4. Temperature variations of the square of the sublattice magnetization (being proportional to I) for $Co_{0.52}Mn_{0.48}$ and $(CoMn)_{0.75}Fe_{0.25}$.

determined from the extrapolation $\bar{\mu}\propto\{1-(T/T_N)^2\}$ based on the band theory[12] or on the spin wave theory.[13] The value is given to be $0.6\pm0.2\ \mu_B$ and $0.7\pm0.1\ \mu_B$ respectively. While the Néel point is determined from the extrapolation of $I_M\propto\bar{\mu}^2\propto\{1-(T/T_N)\}$ based on the itinerant electron theory or on the molecular field theory. The point was estimated to be 343 ± 2 K and 259 ± 1 K for $Co_{0.52}Mn_{0.48}$ and $(CoMn)_{0.75}Fe_{0.25}$ respectively, which are smaller than those obtained from the magnetic measurement[1] given as $T_N\simeq370$ K and 310 K respectively.

In Fig. 5, the square of the normalized sublattice magnetization is plotted against normalized temperature, where the Néel point determined from this result is used. The tail near T_N is regarded as the effect of the magnetic short range order. In the figure, the variation obtained from Brillouin function with $S=1/2$ and that derived from Stoner model given by Lidiard[12] are shown. The experimental result fits better the latter than the former, then this is reasonable for the band antiferromagnetism of $(CoMn)_{1-x}Fe_x$.[2] Some discrepancy is supposed to be due to the gap effect[1] in the band antiferromagnetism.

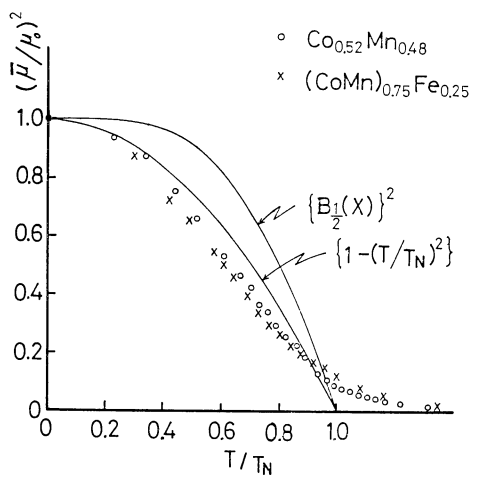


Fig. 5. Theoretical fits for the square of sublattice magnetizations of $Co_{0.52}Mn_{0.48}$ and $(CoMn)_{0.75}Fe_{0.25}$.

D. *The diffuse pattern around* $(100)_M$

In $Co_{0.52}Mn_{0.48}$, some diffuseness of the $(100)_M$ reflection appeared near the Néel point. Here, the result is shown briefly. Making use of 4-circle neutron diffractometer, the observation at room temperature, which is just below the Néel point, has been done in the two dimentional (001) plane in the region $H=0.80\sim1.50$, $K=-0.20\sim+0.20$ and $L=0$ with the interval of 0.02, where the Bragg peak of $(200)_N$ and $(220)_N$ was taken as a standard.

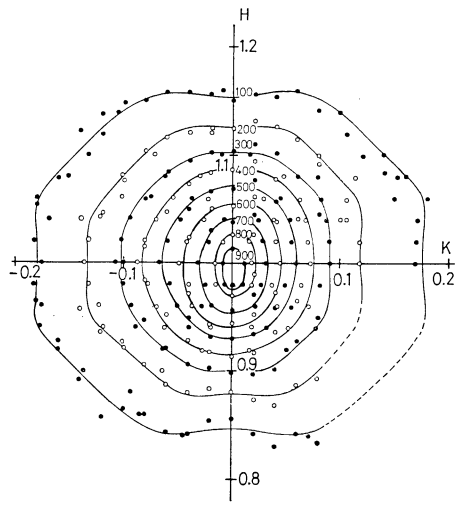


Fig. 6. Magnetic diffuse patterns around $(001)_M$ of $Co_{0.52}Mn_{0.48}$ at room temperature.

The obtained result for the contours around $(100)_M$ is shown in Fig. 6. In this figure, the corrections for the magnetic form factors[10,11] and for the thermal diffuse scattering have been carried out, however the resolution correction has not been done yet. Though the figure contains the normal magnetic Bragg reflection at the center because of the result below T_N and the contour must change its shape if the resolution correction is taken into account, it is clearly the magnetic reflection $(100)_M$ possesses the diffusive property near the T_N (presumably just above T_N). It is noted, if the total diffuse reflection including Bragg intensity of the $(100)_M$ is regarded as that due to the spin inclination mentioned above, the inclination angle of $\theta=30\pm3°$ can be estimated from the comparison with the $(110)_M$ intensity.

Two causes for the diffuseness of the $(100)_M$ can be considered. The one is due to a spacial short range order correlation for the spin inclination angles being represented by

$$d\sigma/d\Omega=(e^2\gamma/mc^2)|f(\boldsymbol{K})|^2\sum_{j=0} m_j \exp(i\boldsymbol{k}\boldsymbol{R}_j)\ ,$$

$$\text{with}\quad m_j=\langle \boldsymbol{S}_{0\perp}\boldsymbol{S}_{j\perp}\rangle-\langle \boldsymbol{S}_{0\perp}\rangle\langle \boldsymbol{S}_{j\perp}\rangle\ , \qquad (6)$$

where the $\boldsymbol{S}_{j\perp}$ means the perpendicular component of the inclined spin at j-th site $\boldsymbol{R}_j$. While, the other, as has been pointed out by Endoh and Ishikawa,[4] depends on an inelastic scattering in relation to excited states in the antiferromagnetic spin system. In order to make clear the origin and to accomplish the analysis, the more detailed experiments including the resolution correction and the energy analysis are desirable.

E. Mössbauer investigation of $(CoMn)_{0.7}Fe_{0.3}$

The average moment of the antiferromagnetic $(CoMn)_{1-x}Fe_x$ was given as 0.6 to 0.7 μ_B. With the purpose to know the contribution of the moment of Fe, Mössbauer experiment has been done at 77.3 K and 300 K for the sample $(CoMn)_{0.7}Fe_{0.3}$ with the Néel point of 308 K.

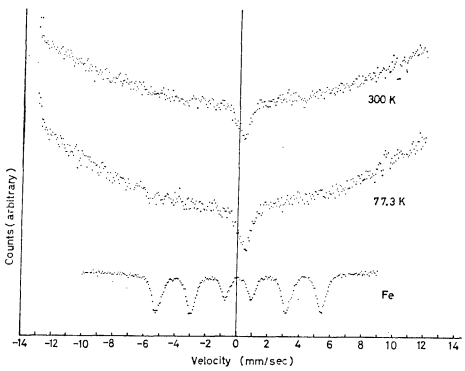


Fig. 7. Mössbauer spectrums of $(CoMn)_{0.70}Fe_{0.30}$ at 77.3 K and 300 K.

The obtained result is shown in Fig. 7. As seen in the figure, the internal magnetic field is weak and the field can be determined by an analysis of the width of the main absorption line. The field is obtained to be 30 ± 10 kOe at 77.3 K and this agrees with that of γ-Fe.[14] Thus, assuming the linear relation between the moment and the field,* the moment of Fe in this system can be estimated as about 0.2 μ_B, which gives somewhat smaller value than the average moment obtained above. The isomer shift at room temperature was 0.4 mm/sec for the stainless steel as a standard.

§ 4. Discussions

As shown above, the antiferromagnetic structure of $(CoMn)_{1-x}Fe_x$ is very similar to that of γ-Fe[3] as for the spin ordering of CuAu type, the magnetic moment with less than 1 μ_B and the spin inclination from the c-axis. It is considered from the magnetic measurement shown in the preceding paper, that the most region of antiferromagnetic γ-phase in the Co-Mn-Fe alloys having $8.3>e/a>7.8$[1] may have the same spin structure, where the structure have been confirmed also in the binary Fe-Mn system[5] for $e/a>7.8$. The similar structure has also been found in the fcc $(CrNi)_{0.3}Fe_{0.7}$[4] with $e/a=8$. It is presumed that the antiferromagnetic properties of $Fe_{0.65}(Ni_{1-x}Mn_x)_{0.35}$[15] for $e/a<8.4$ suggest to have the similar spin structure. Consequently, it is regarded that the fcc transition metal alloys can have the γ-Fe like spin structure in the vicinity of $e/a\sim8$.

The antiferromagnetic and the structural parameters of the γ-Fe like alloys mentioned above are tabulated in Table II. These alloys have the average moment of less than 1 μ_B and the spin inclination. The results suggest that the origin of spin structure is due to the similar band structure. So far as the Néel point is concerned, however, the considerable difference can be seen for these substances. This implies variations of the magnetic interaction for the alloys.

On the other hand, when the Néel points are plotted against the lattice parameter for these

* Recently, we have reported that the linear relation between the moment and the field can not be held in the bcc and the fcc ferromagnetic intermetallic compound Fe_3Ga: N. Kawamiya, K. Adachi and Y. Nakamura: J. Phys. Soc. Japan 33 (1972) 1318.

Table II. The antiferromagnetic and the structual parameters of γ-Fe like alloys with $e/a=8$.

	e/a	$\theta(°)$	$\phi(°)$	$\bar{\mu}(\mu_B)$	$T_N(°)$	a(A)
γ-Fe	8	18.7		(0.7±0.1)	67	3.57 (extrapolated)
stainless ($Fe_{0.70}Cr_{0.15}Ni_{0.15}$)	8	(4±4)		(0.4±0.03)	(21±1)	3.58
$Fe_{0.65}(Ni_{0.33}Mn_{0.67})_{0.35}$	8				270	3.594
$Co_{0.52}Mn_{0.48}$	8	(9.1±0.5)	45	(0.6±0.2)	(343±2)	(3.606 ±0.003)
$(CoMn)_{0.75}Fe_{0.25}$	8	(6.7±0.7)	45	(0.7±0.1)	(259±1)	(3.590 ±0.003)

γ-Fe like antiferromagnetic alloys, a universal relationship can be given in Fig. 8, where the lattice parameters in the antiferromagnetic state are used. This result can be understood that the magnetic interaction depends on the interatomic distance regardless of the constitutional elements for these alloys.

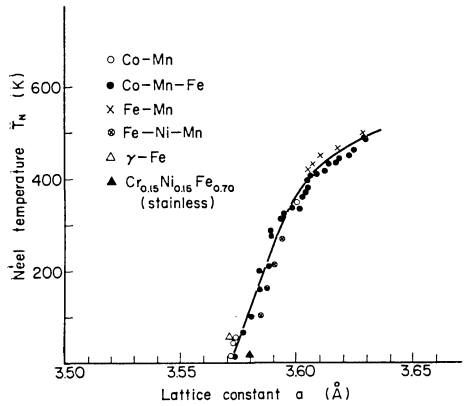


Fig. 8. Néel points vs lattice constants for the various γ-Fe like antiferromagnetic alloys.

While in the preceding paper,[1] the system $(CoMn)_{1-x}Fe_x$ was characterized as the gap type antiferromagnetism in the band magnetism. Accordingly, as for the interatomic distance and the magnetic interaction, the following explanation can be derived. The magnitude of the band gap energy which relates to the magnetic interaction depends seriously on a change of the lattice parameter, though the band shape as a whole giving the spin structure does not change so much. By this description, it can be understood that the contour lines of T_N, $\chi(T_N)$ and the lattice parameter a in the ternary Co-Mn-Fe system exhibit the similar tendency as has been noted in the discussion of the preceding paper.

In conclusion, we have determined the spin structure of $(CoMn)_{1-x}Fe_x$ for $x=0$ and 0.25 by the single crystals and the structure was given to be similar to that of γ-Fe, where the inclination angle of spin at 77.3 K and the temperature dependence of the sublattice moment were obtained, and some diffuse scattering of CoMn around the $(100)_M$ magnetic reflection just below the Néel point was found. A universal relationship between the Néel point and the lattice parameter for the γ-Fe like antiferromagnetic alloys was found and an interpretation about the fundamental magnetic properties reported in the preceding paper was given.

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